PMM Science Team Meeting 2019

Assessment of snowfall observational capabilities of GMI and ATMS through the exploitation of observational datasets

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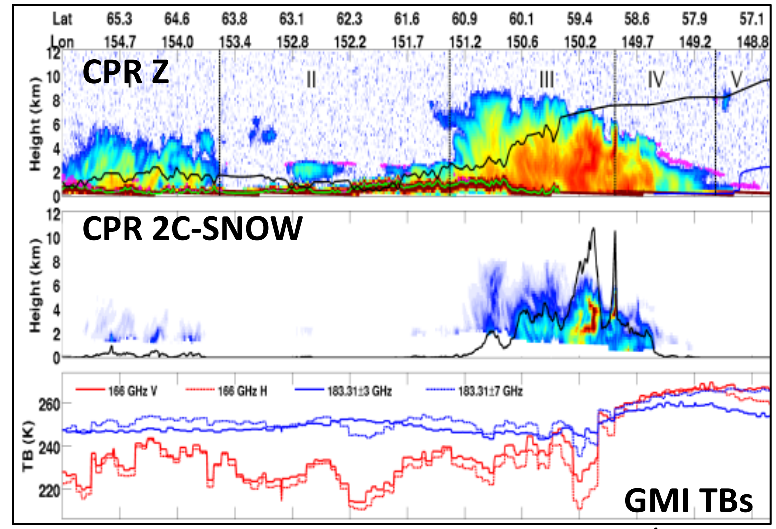
Motivations and Goals

1. Proven/shown sensitivity of the PMW sensors to the presence of snow/ice clouds and (indirectly) to snowfall
   - Satellite-based snowfall detection and quantification remains a big scientific challenge (high latitudes)
2. Studies based on GPM/CloudSat-Calipso coincidence dataset demonstrate:
   - impact of supercooled liquid water and environmental conditions on GMI snowfall spectral signature
   - Great potentials for algorithm development (e.g., SLALOM, Rysman et al., 2018, 2019)

Snowfall event - Eastern Siberia 30 April 2014



Panegrossi et al., 2017

Objectives

1. Contribute to LSWG intercomparison/validation experiment of GPM-era snowfall products
2. Extend analysis of snowfall detection capabilities to other PMW radiometers (ATMS) using CloudSat
   – Understand interconnection between supercooled water, environmental conditions (frozen background surface and TPW) , and cloud vertical structure, on PMW snowfall spectral signature

GPM-era MW products validation experiment

Objective quality assessment of currently available snowfall MW-based products using ground-based radar measurements

- Ground-based snowfall datasets:
  - **MRMS datasets:**
    - **Case study analysis (13 cases selected based on CPR/GPM coincidences)**
      - 0.01°x0.01° resolution at 2 min time step with the indication of quality and phase
    - **One year statistical analysis (01 May 2014-31 May 2015)**
      - MRMS dataset matched with GMI (at 15 km resolution) with indication of phase
  - **Operational NEXRAD network polarimetric measurements (for case studies analysis);**

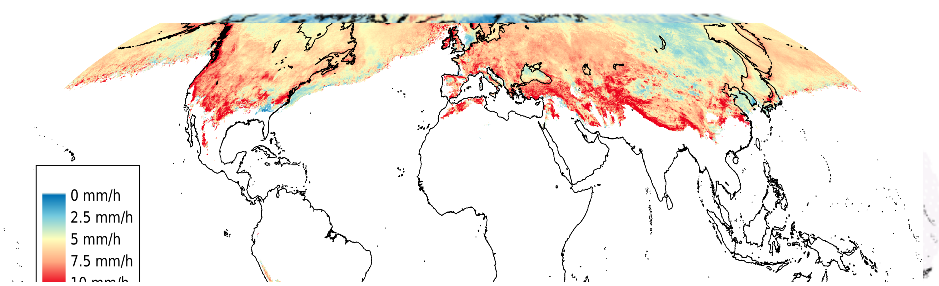
- MW snowfall products considered :
  - GPM DPR products (V05)
  - CloudSat CPR products (V05)
  - **GMI products (NASA GPROF (V05), CNR-ISAC SLALOM)**
  - ATMS and MHS products (NASA GPROF, NOAA, CNR-ISAC 183-WSL)

SLALOM: Snowfall retrieval algorithm for GMI

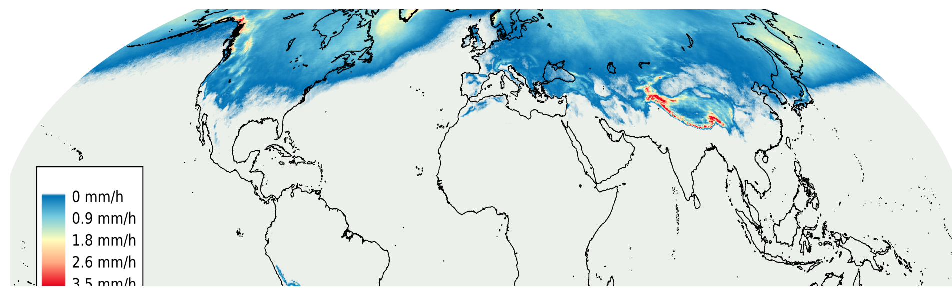
It is based on the GMI/CPR coincidence dataset V03B (Joe Turk, JPL)
Input: GMI L1c TBs (all channels) and auxiliary ECMWF analysis variables
No auxiliary info on background surface conditions;
Random forest modules for snowfall detection and supercooled liquid water detection (***at the cloud top***);
Multi-linear regression: snow water path (SWP) estimates (Rysman et al., Rem. Sens., 2018)
New gradient boosting module for Surface snowfall rate (SSR) (Rysman et al., GRL, 2019)

Mean SSR (mm/h) between May 2014 and May 2017

Conditioned (SSR > 0 mm/h)



Unconditioned

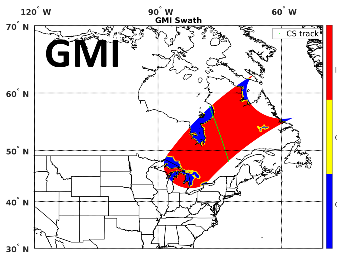


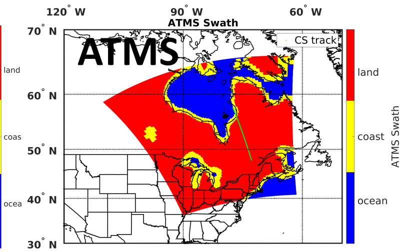
SLALOM main limitations:

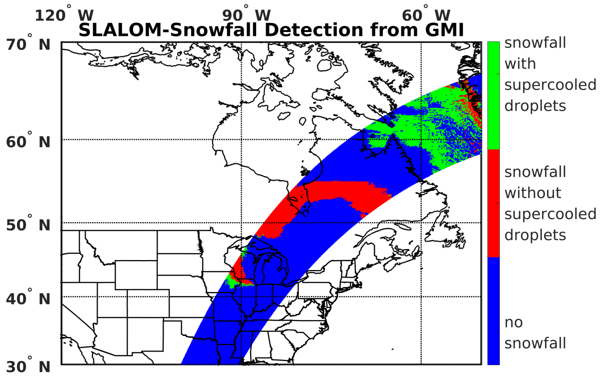
- **SLALOM fully relies on the 2C-SNOW-PROFILE CPR product (V04)**, e.g., misses lower layers, no mixed-phase precip., underestimation higher snowfall intensity;
- GMI/CPR observations mostly occur around 60°N/S and are affetcted by daylight-only mode of CloudSat;
- Effect of embedded supercooled droplets is not considered (30% of cases)

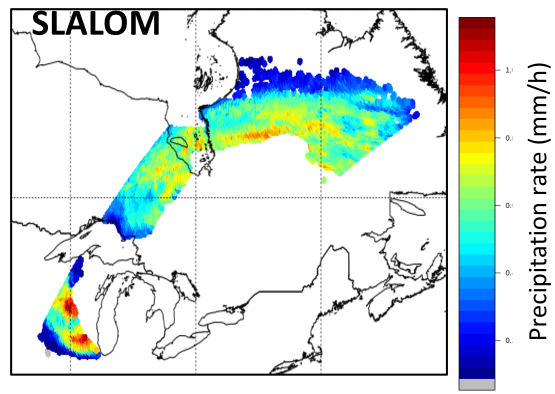
Snowfall event 24 November 2014 over U.S./Canada

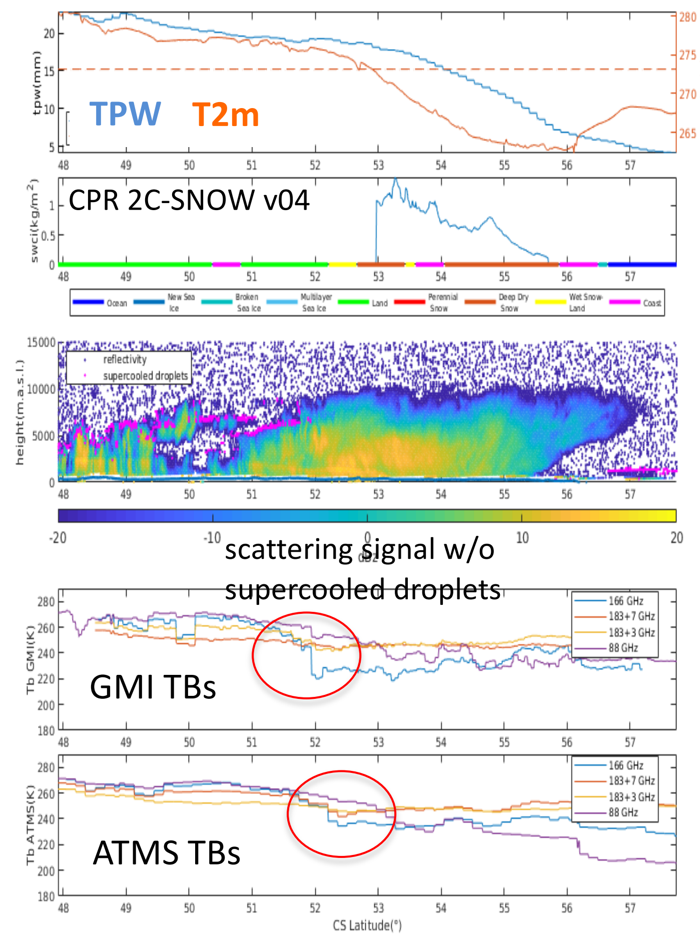
GPM (DPR GMI)
CloudSat/Calipso
ATMS

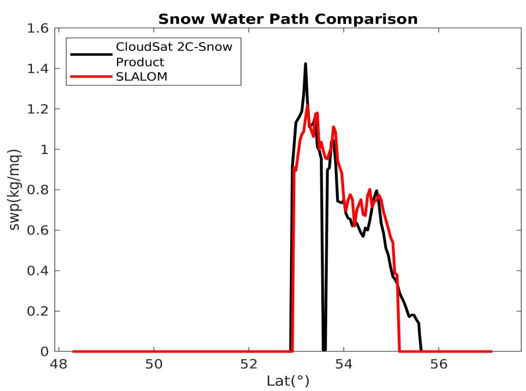


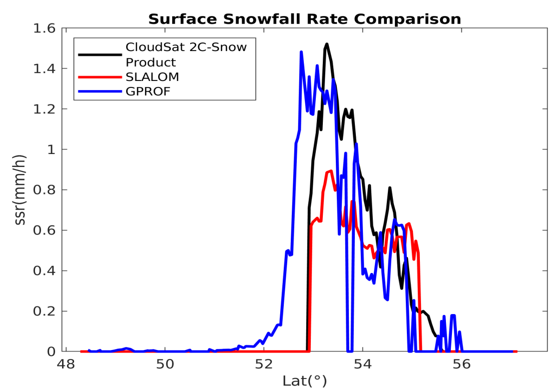




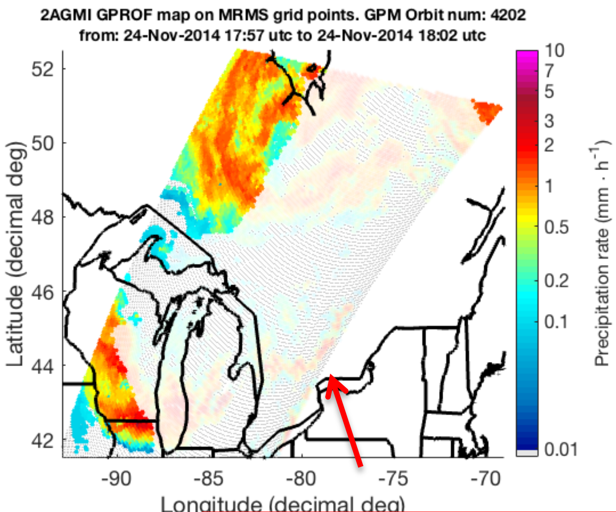


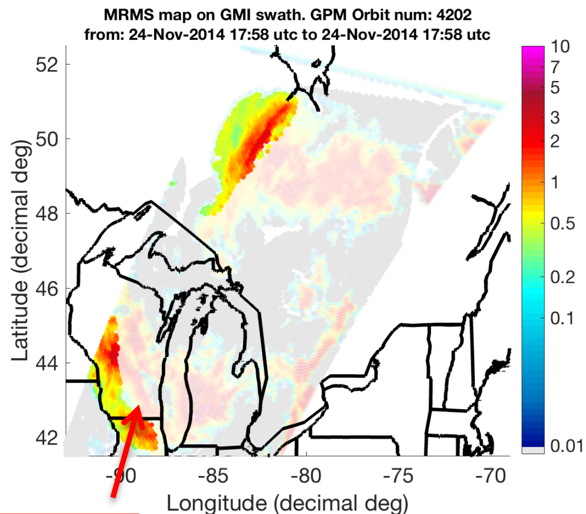


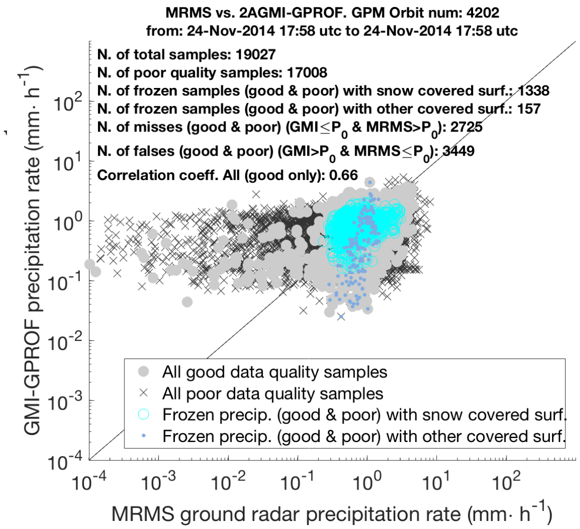




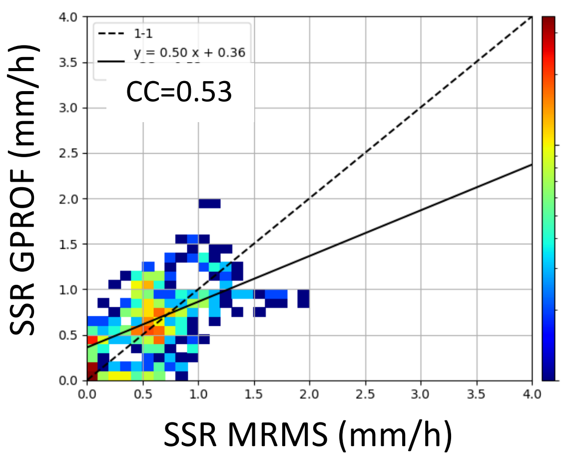
Case study 24 Nov. 2014 orbit 4202: MRMS vs. GPROF and SLALOM

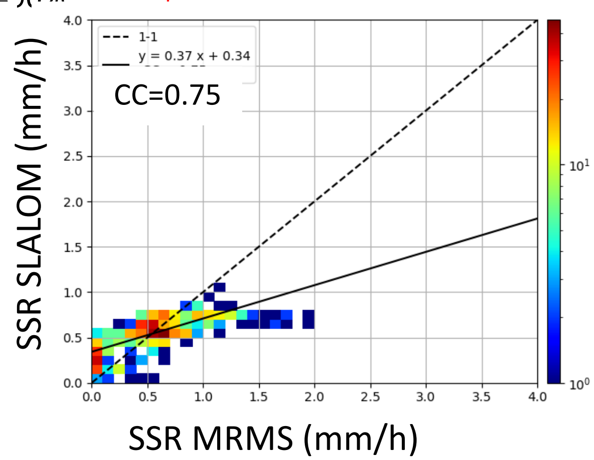


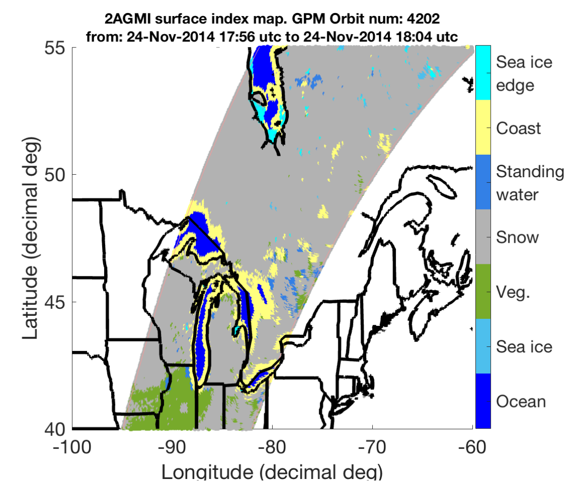




GMI Frozen fraction >=90%





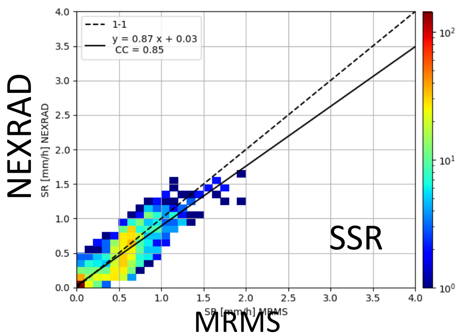


SR estimates from NEXRAD polarimetric measurements (Z and K_{DP})

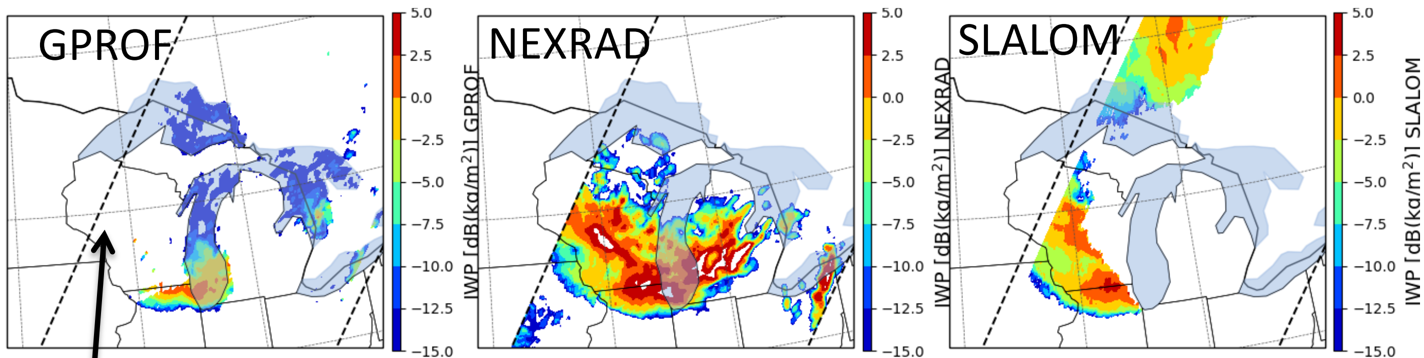
Bukovcic et al (2018)

$$S(K_{\mathrm{DP}}, Z) = 1.48 K_{\mathrm{DP}}^{0.61} Z^{0.33}$$

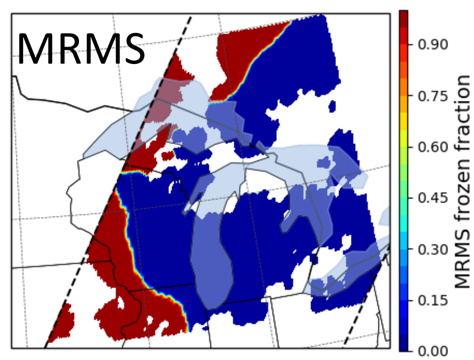
$$\mathrm{IWC}(K_{\mathrm{DP}}, Z) = 0.71 K_{\mathrm{DP}}^{0.65} Z^{0.28}.$$

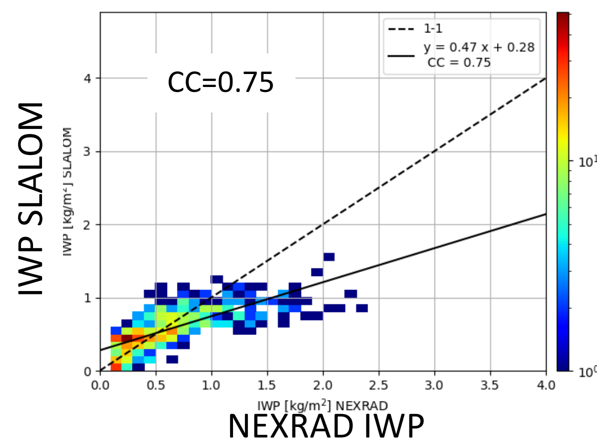


IWP



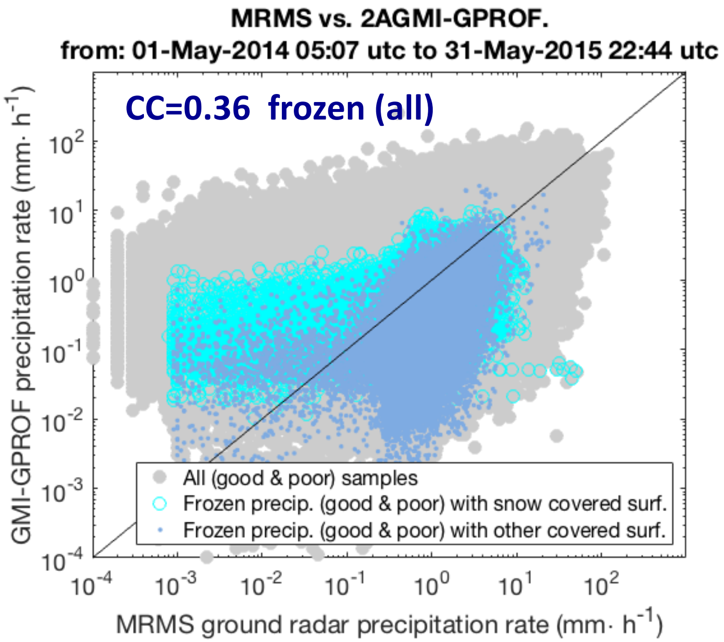
GPROF IWP
is not available
over snow covered
surface
(a priori SSR database
based on MRMS)



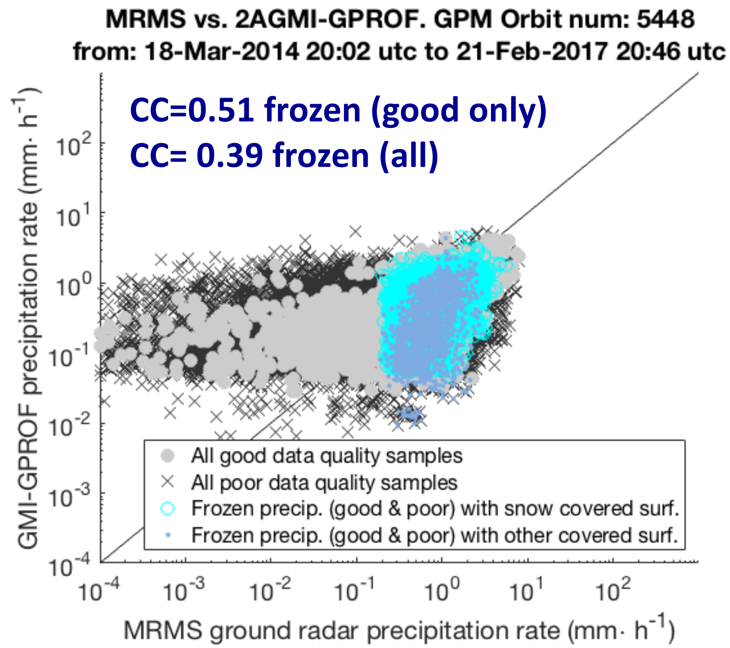


GPROF vs. MRMS: case studies and one-year analysis

May 2014-May 2015 one year analysis



13 Case studies analysis



GMI &MRMS Frozen fraction >=90%

2014/15 analysis

SR>0.01 mm/h	CC	Bias (GV-PMW)	RMSE
Snow Surf.	0.31	0.33 mm/h	0.80 mm/h
Other surf.	0.47	0.61 mm/h	1.08 mm/h

Case studies

SR>0.01mm/h	CC	Bias (GV-PMW)	RMSE
Snow. Surf.	0.40	0.16 mm/h	0.58 mm/h
Other surf.	0.44	0.42 mm/h	0.63 mm/h

Concluding remarks on validation/intercomparison experiment

- Intercomparison/validation between MW (active and passive) snowfall products is challenging, due to inconsistencies (i.e., “surface snowfall” definition) and scarcity of high-quality GV datasets;
  - **Extend validation experiment to other regions (Finland IKA ground-based radar dataset)**
  - **Compare statistics of NASA, NOAA, CNR-ISAC GPM-era products vs. MRMS and IKA datasets**

- SLALOM approach seems very promising (right pattern) but it reproduces main features of CloudSat/GMI coincidence dataset
  - Tuned for higher latitudes, underestimation of higher snowfall rates
  - Extend validation to the one-year MRMS dataset

- GPROF shows underestimation with respect to MRMS (less over snow covered surface MRMS-based), and lower correlation than SLALOM; good agreement with CPR for US/Canada frontal snowfall systems;

- IWP polarimetric ground-radar estimates: good agreement with SLALOM SWP (but underestimation for higher snowfall intensity)

Global ATMS CPR coincidence dataset

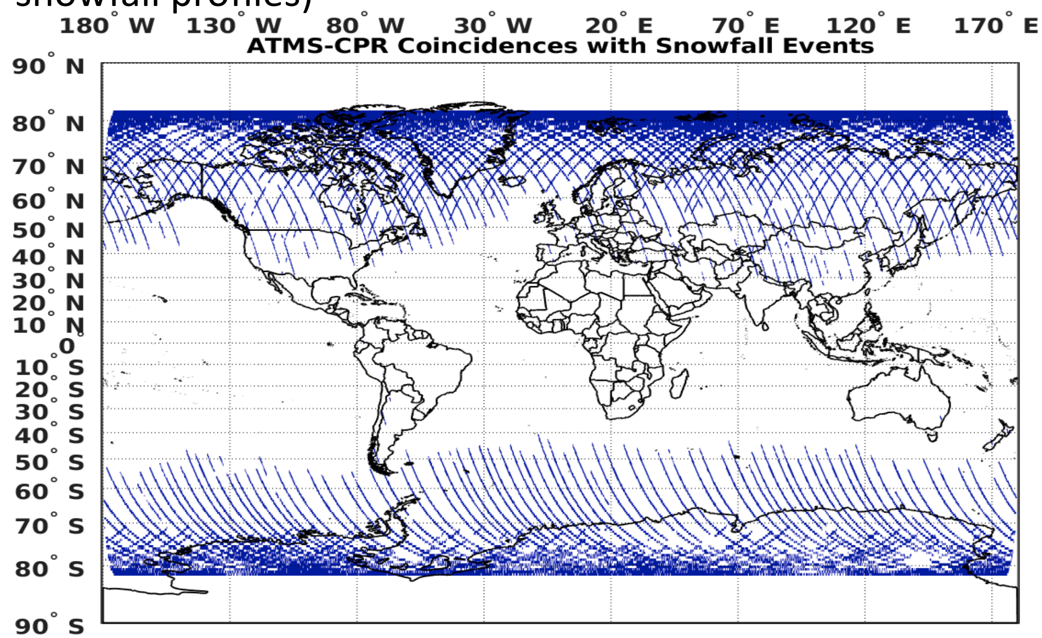
Why cross-track scanning ATMS?

- 9 channels from 23 to 190 GHz
- On board current and future U.S. **operational *polar satellites***
- Future launch of EPS-SG MicroWave Sounder (MWS) (similar to ATMS)

Main products in the dataset

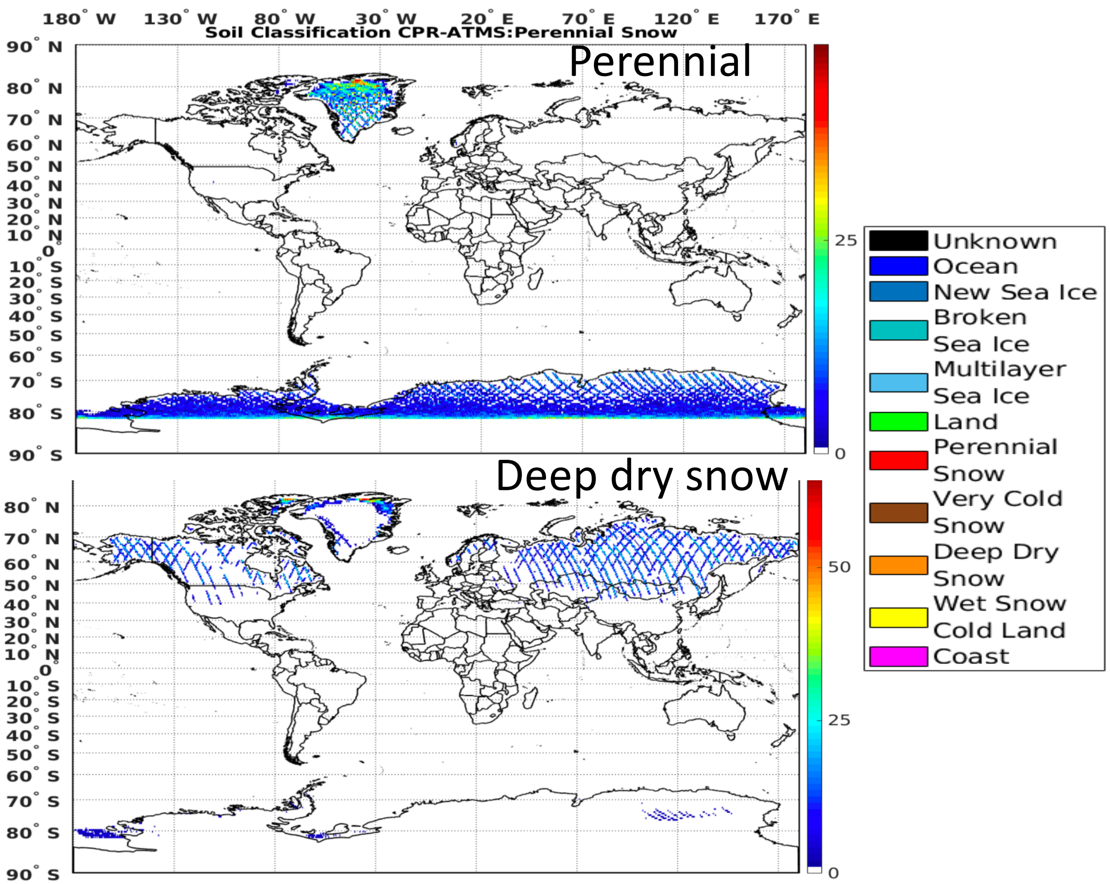
- ATMS L1c TBs
- CloudSat V05 products (SWP available for SSR=0 mm/h)
- ECMWF-AUX and ERA-5 Ancillary environmental variables
- Supercooled droplet occurrence (CloudSat/Calipso ICARE DARDAR product)
- MODIS products (cloud top height)

- Over 4.5 M elements from 2015/01/01 to 2016/08/31
- **750K snowing profiles (16%)**
    - 105K with supercooled droplets at cloud top
    - 435K w/o supercooled droplets at cloud top (could be embedded)
    - 211K no information about supercooled droplets (28% of snowfall profiles)



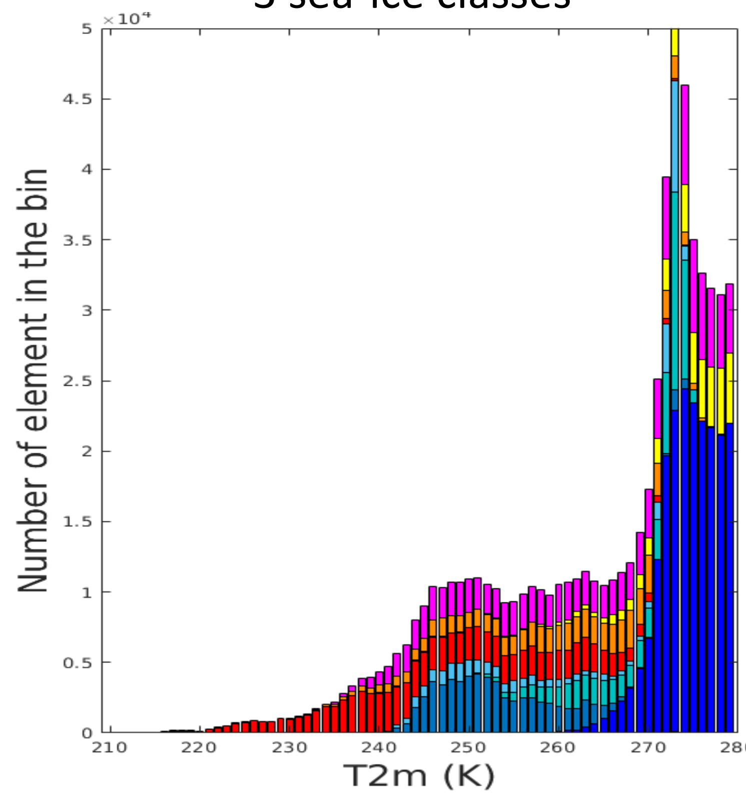
CNR-ISAC ATMS-based surface classification

Based on 23 GHz and 31 GHz channels and ECMWF-AUX surface temperature

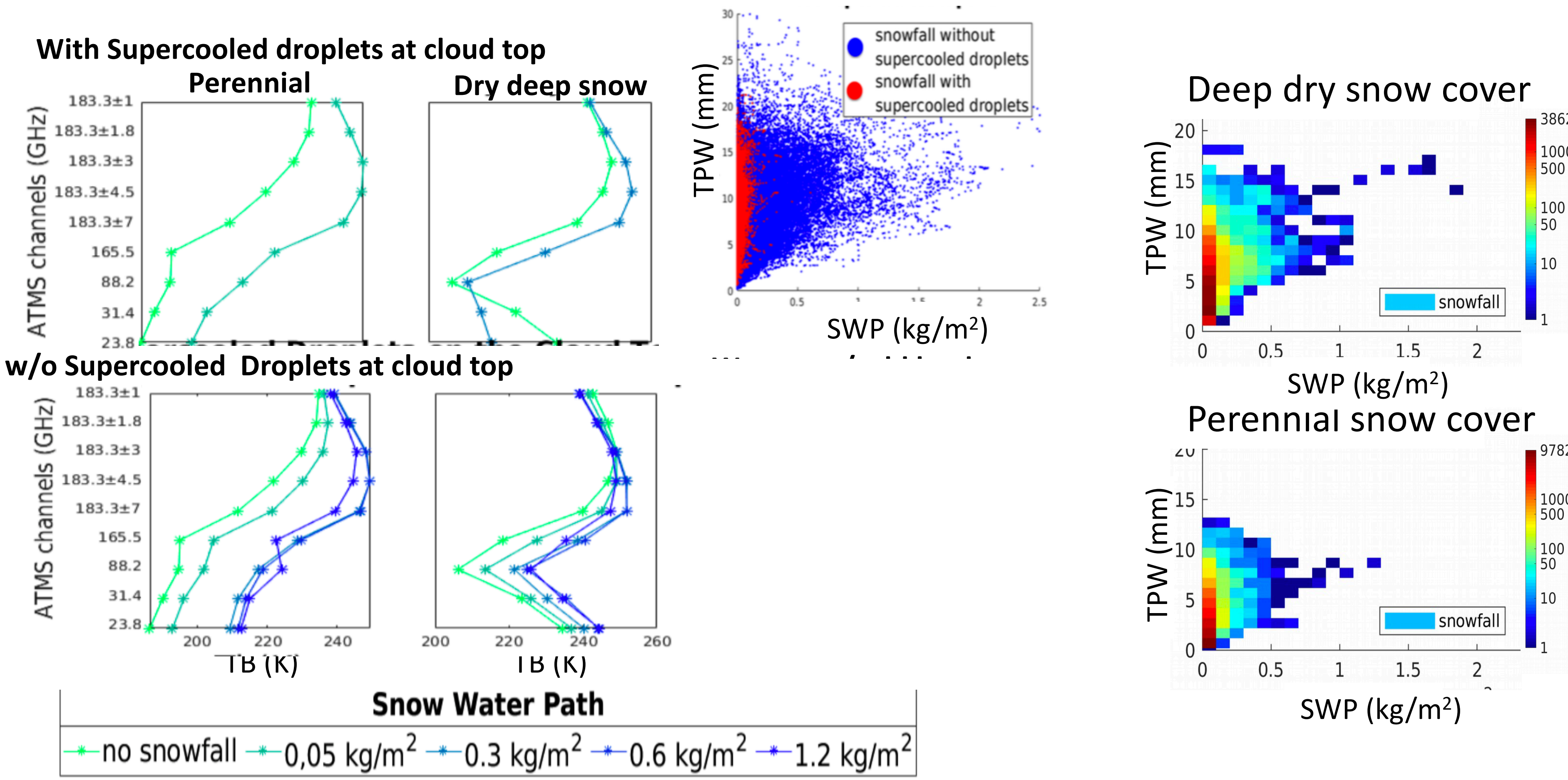


4 snow-cover classes

3 sea-ice classes

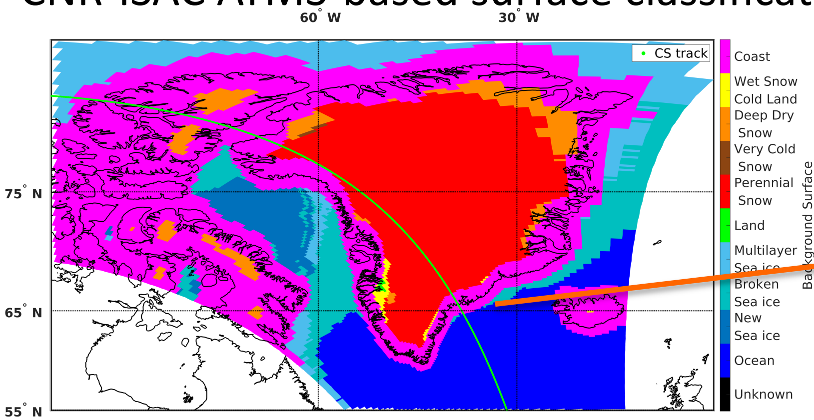


Global analysis: TB dependance on SWP

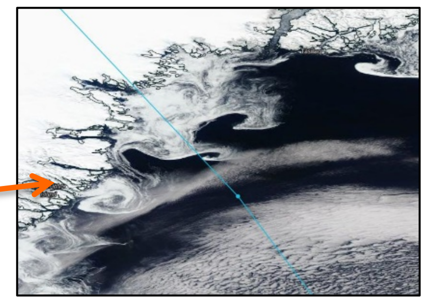


Greenland Case study 24 April 2016

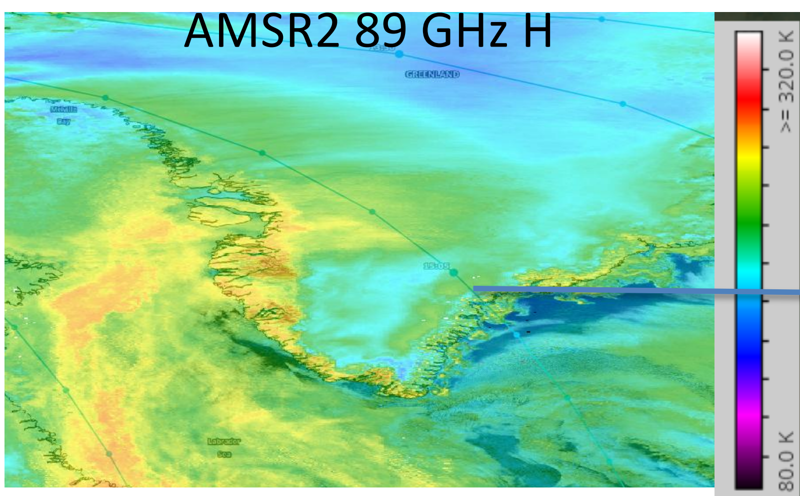
CNR-ISAC ATMS-based surface classification

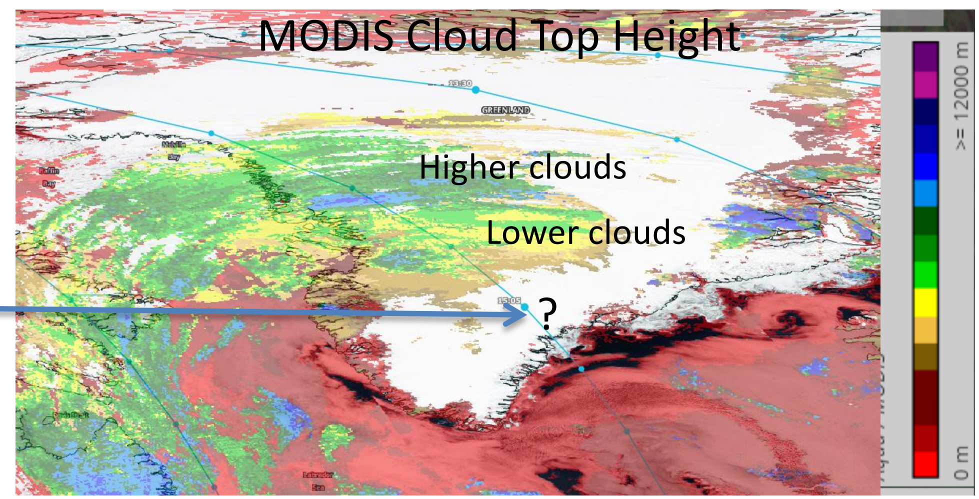


MODIS VIS RGB



Coast line characterized by very complex features





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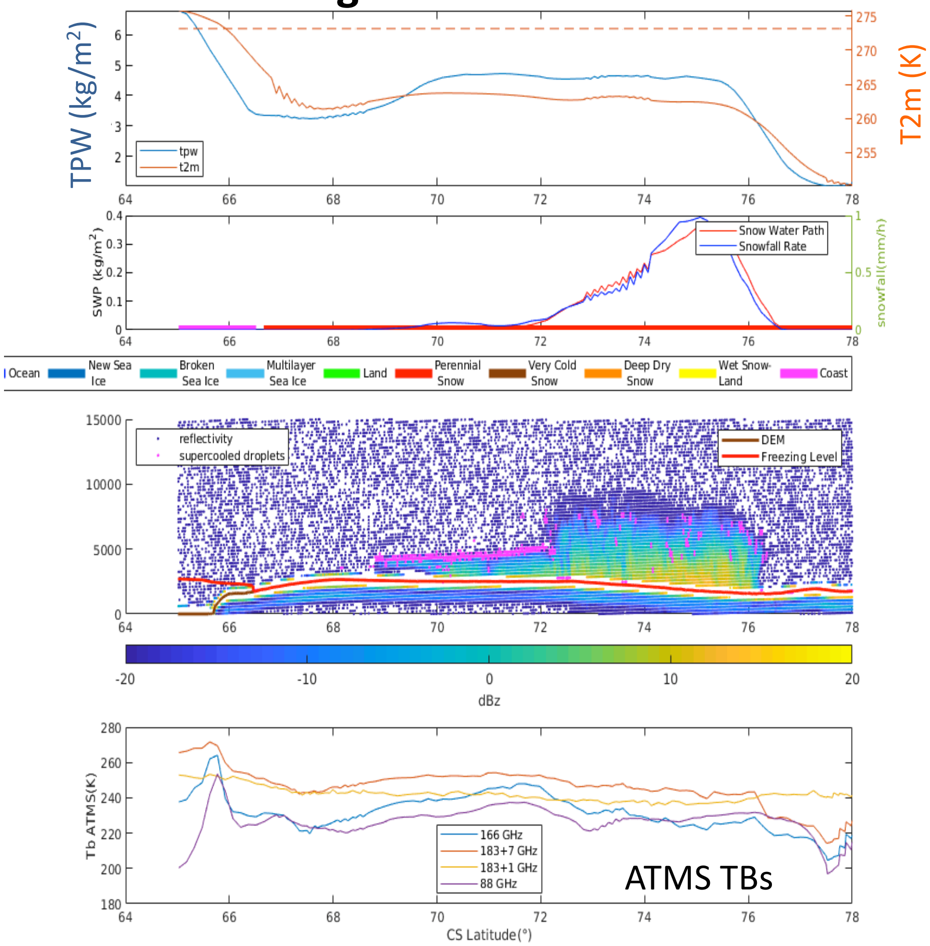
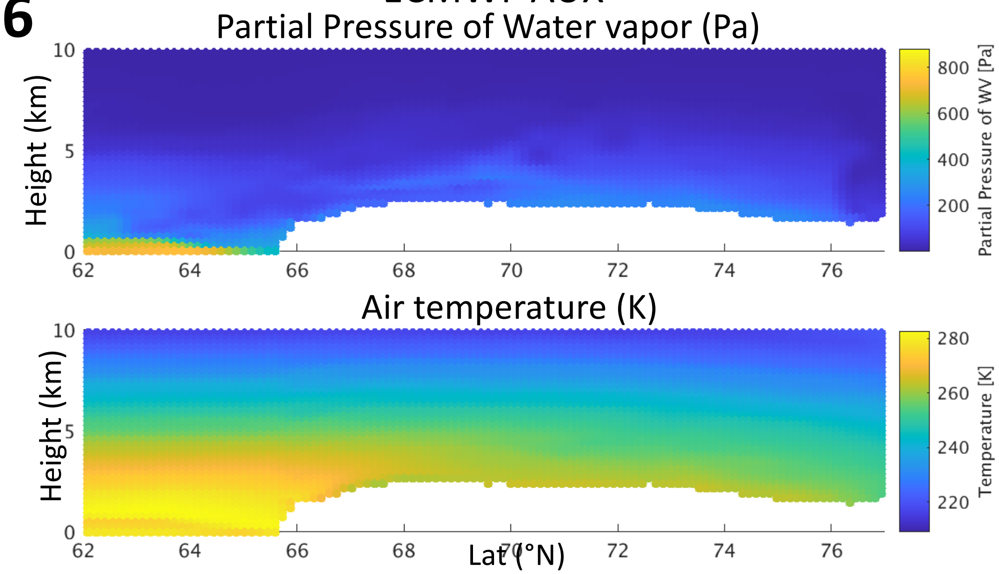
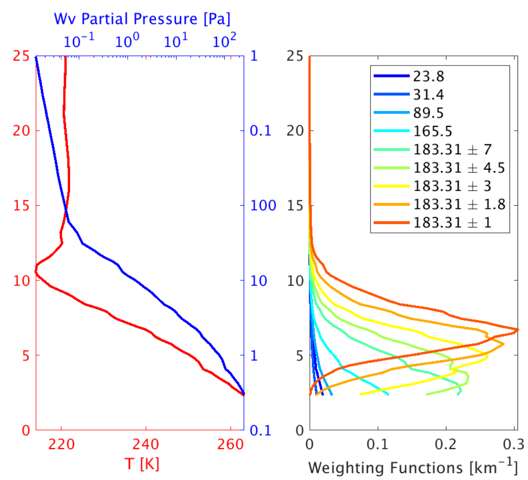
Along the CloudSat track



ECMWF AUX

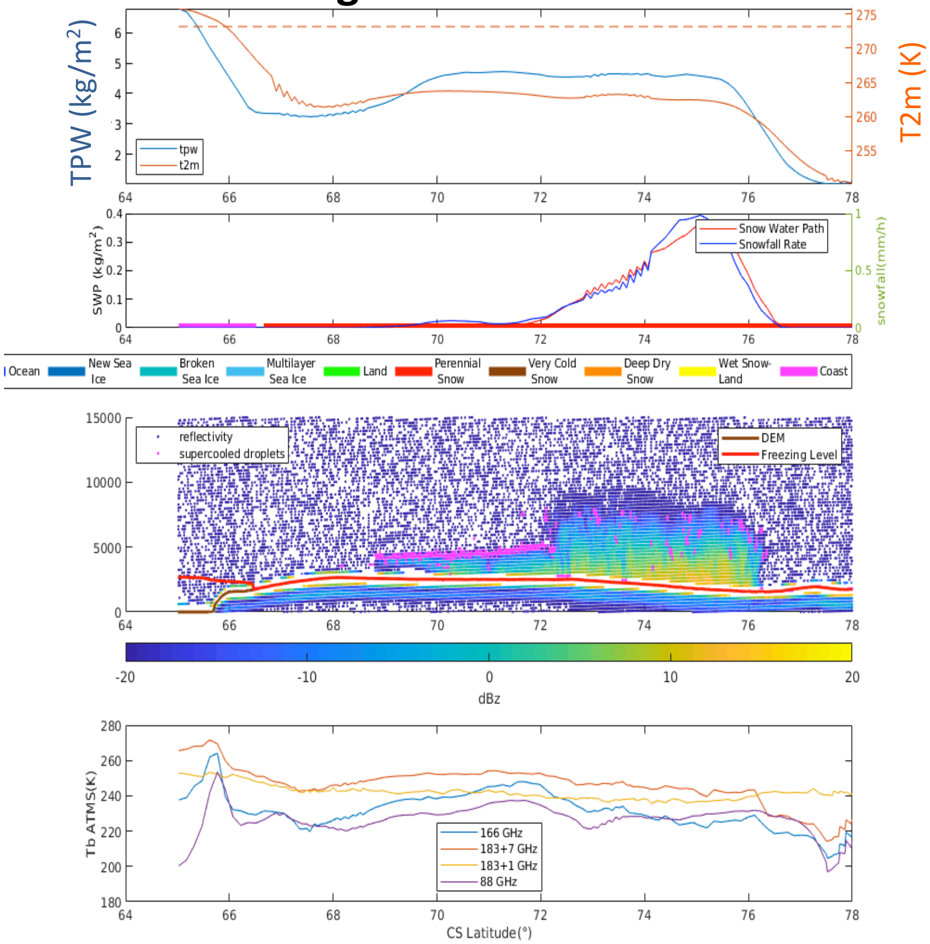


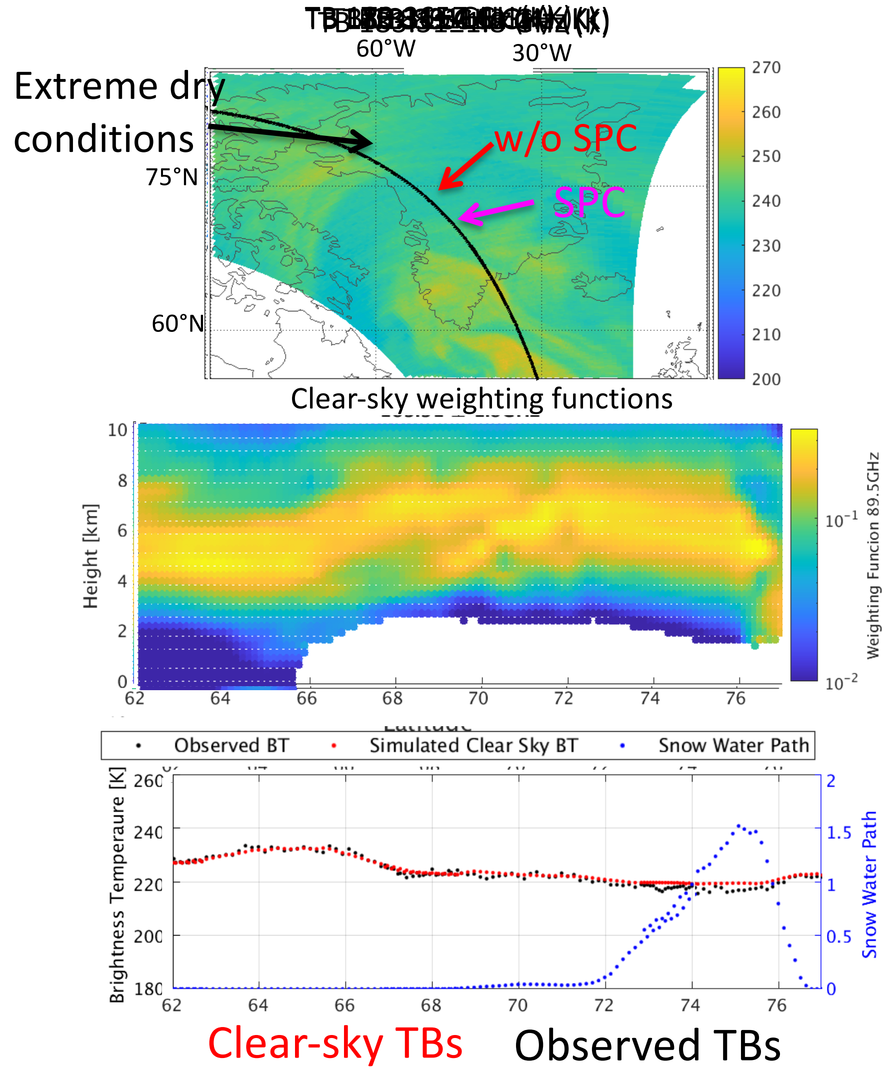


ATMS channels clear-sky weighting functions for mean T and WV profile over the Greenland plateau

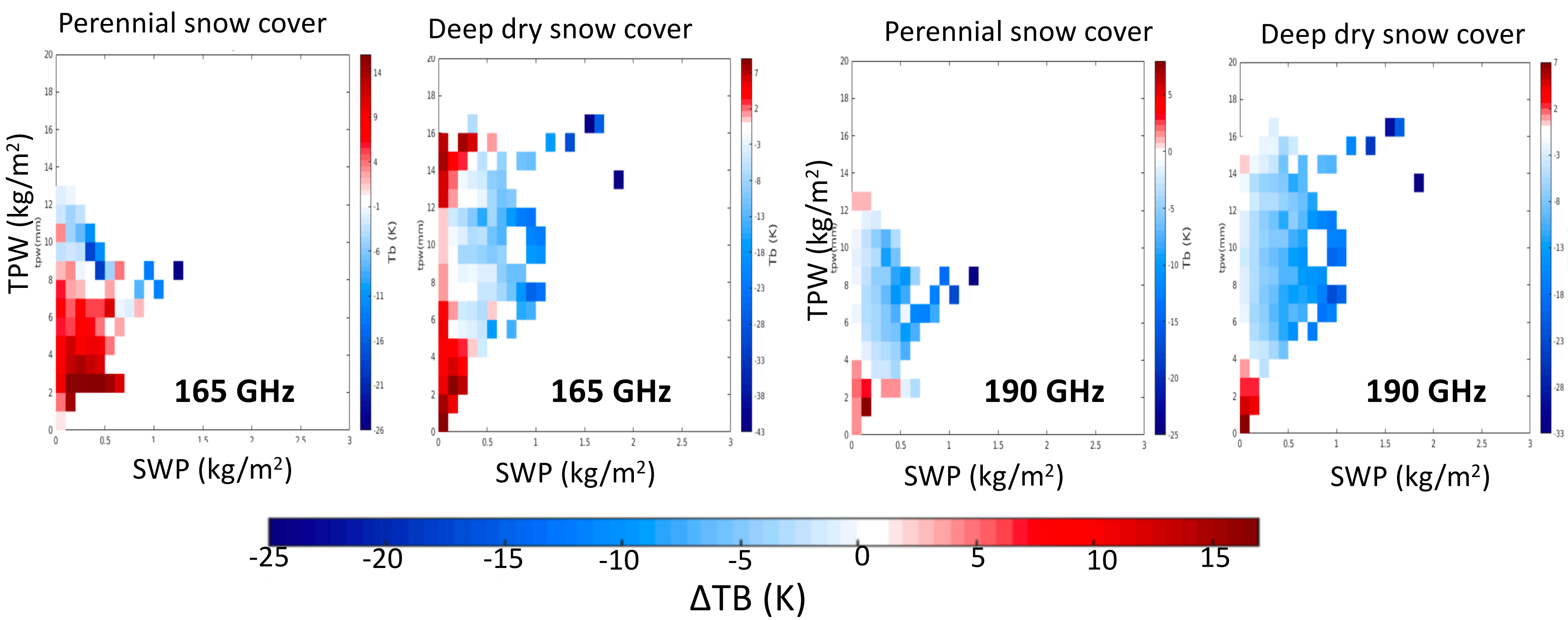
Greenland Case study 24 April 2016

Along the CloudSat track





Global analysis: TB dependence on SWP and TPW



Mean TB difference in TWP/T2m/SWP bins with respect to “clear sky conditions” (SWP=0 kg/m^2,) for each surface type in CloudSat/ATMS dataset

Concluding remarks
CloudSat-based ATMS snowfall signal analysis

- WV and supercooled droplets impact on (weak) snowfall related signal at high latitudes strongly depends on frozen surface conditions

- Knowledge of clear-sky signal at time of the overpass can be very useful for snowfall detection, especially in extreme environments:
  - Characterization of the background surface at the time of the overpass;
  - Good representation of T and WV conditions

- Presence of supercooled droplets need to be carefully accounted for in the algorithm retrieval process (through observational datasets combined with RT simulations)

Acknowledgements

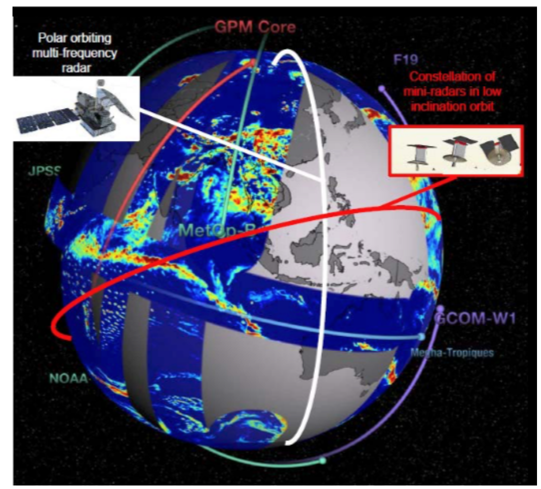
This study is conducted within EUMETSAT HSAF and ESA RainCast Projects
and within the scientific collaboration project between HSAF and PMM Research Program

RAINCAST study

(in response to ESA ITT TT 1-9324/18/NL/NA)

The study aims at identifying and consolidating the science requirements for a **European precipitation satellite mission** that could complement the existing space-based precipitation observing system

(fits the purposes of Earth Observation Science for Society https://eo4society.esa.int)

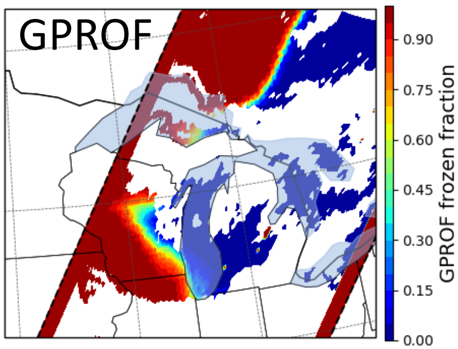


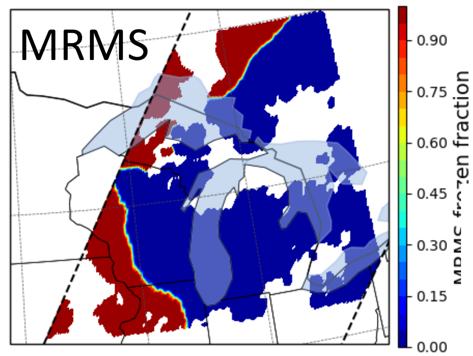
The snowfall challenge in RAINCAST:

1. To assess snowfall observational capabilities of the most advanced currently available space-borne MW sensors through the exploitation of satellite-based and ground-based observational datasets (*gap analysis*)
2. To provide quantitative criteria and guidelines in terms of passive and active MW capability for the design of a future satellite mission for **snowfall global monitoring** (*gap filling*).

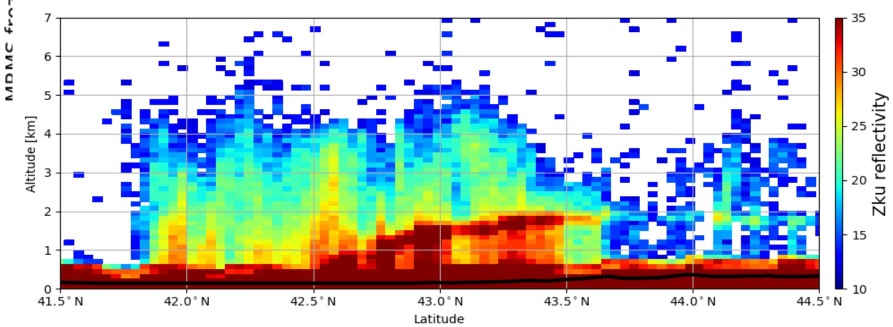
Extra slides

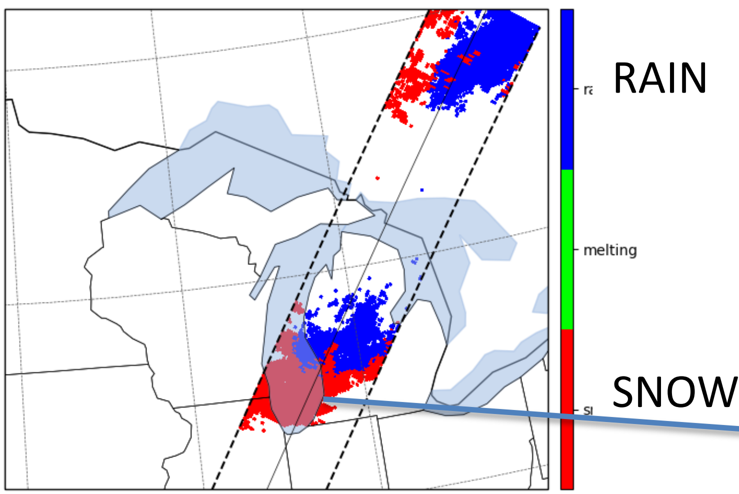
What about phase?



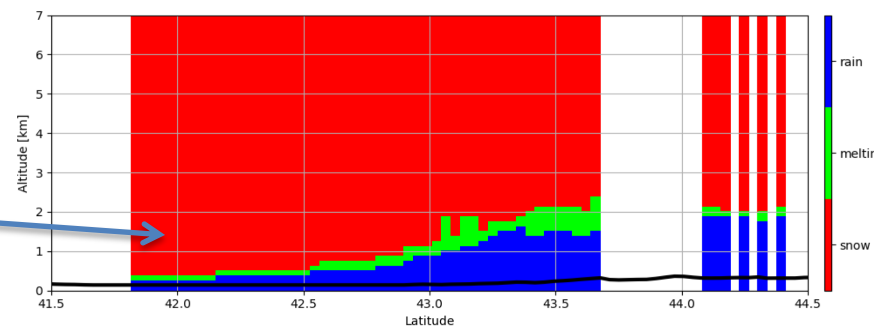


DPR Ku-band Z_m





DPR V5 phase classification



DPR V5 phase classification product
at NSB level (first ground clutter-free level)

The black line denotes ground elevation

Case study Comparisons

- MRMS 1 km vs. GMI-GPROF
- MRMS 1km has been averaged on 15 x 15 km FOV of GMI before performing the comparison.
  - Phase information has been averaged
  - Frozen Mask =100 for Snow and =0 otherwise.
  - Then the MRMS frozen fraction (%) on the GMI 15 km-FOVs is obtained averaging the native 1km-MRMS frozen mask onto GMI 15 km-FOVs.
- Time and space colocation has been applied.

GMI vs. MRMS one year 2014-2015 Comparisons

- MRMS 15 km vs. GMI
- MRMS 15km are already averaged on 15 x 15 km FOV of GMI.
  - Phase information was already average as well and provided as a frozen fraction (%) with values between 0 (fully liquid) and 100 (fully frozen).
  - Time and space colocation was already applied.

MRMS datasets

- **MRMS**
  - MRMS is a US and Canadian effort to provide a Cartesian gridded level II and III radar products at 1 x 1 km horizontal resolution, 2 min time sampling, combining USA and Canadian radar networks.

1. Case studies

13 selected from GMI/CPR (and ATMS) coincidence dataset over US/Canada. MRMS 0.01°x0.01° resolution at 2 min time step with the indication of phase:

- Radar quality index
- Hydrometeor phase mask
- Precipitation rate
- hourly Gauge / Radar ratio (for liquid precipitation only)

MRMS coverage and quality index